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Further progress is reported for the second year of a project to investigate the transmission ecology of tick-borne Crimean-Congo Hemorrhagic Fever virus (CCHFV) in the West African savannah. Long-term, prospective observations were continued at 3 sites in northern Senegal; other studies of virus transmission were performed in Mauritania. Adult tick activity on domestic ungulates appears seasonal for the major *Rhipacephalus* spp., but equivocal for *Hyalomma* spp. Immature ticks feeding on small mammals and birds are most abundant during and just after the rainy season. The prevalence of anti-CCHFV antibodies is high among cattle and sheep in our northern study areas, and falls to near zero with increasing rainfall and vegetation in southern Senegal. Monthly sero-conversion incidence rose precipitously during a period when adult *Hyalomma* were unusually abundant. Maternal transmission of IgG antibodies was observed. The spatial distribution of human infection rates correlated with that for domestic animals. Human cases, one fatal, were studied during a period of epizootic transmission among sheep. CCHFV was isolated from pools of *H. truncatum* and *R. guilhoni*.

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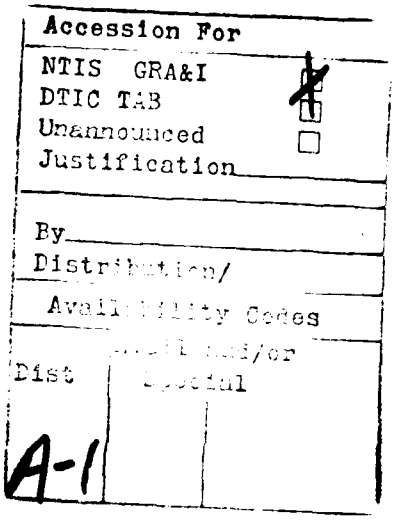

ANNUAL REPORT

Mark L. Wilson and Jean-Pierre Digoutte

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SUMMARY

Crimean-Congo Hemorrhagic Fever (CCHF), a life-threatening tick-borne viral zoonosis, occurs in portions of southern U.S.S.R, central Asia, southern Europe, the Middle East, and the entire African continent. Nearly 30 Ixodid tick species, most notably of the genus *Hyalomma*, have been found to be infected by CCHF virus (CCHFV) however little is known of their importance in maintaining transmission in nature. Various species of wild mammals exhibit CCHFV antibodies, yet the role of such vertebrates in horizontal transmission or amplification of the virus remains undefined.

During the second year of this proposed three year project, we cataloged the most prominent vertebrates and ticks indigenous to three long-term study sites in northern Senegal. Prospective longitudinal analysis of the tick and vertebrate fauna at Dahra, Yonofere, and Bandia continued throughout the year. Nearly 10 tick species are being studied, most notably *H. impeltatum*, *H. marginatum rufipes* and *H. truncatum*, all believed to be important vectors of CCHFV. Immature ticks and serum samples are being taken from birds and small mammals including the genera *Mastomys*, *Arvicanthis*, and *Taterillus*, which are considered candidate reservoirs. Domestic ungulates are being sampled regularly in studies of adult tick seasonal activity, density and host associations; more than 1,500 cattle and sheep have been thusly examined.

Studies of vertebrate infection are designed to estimate risk, define temporal and spatial distribution of transmission, and clarify their role in the natural cycle of CCHF virus transmission. Analysis of IgG antibodies in more than 900 sheep sera collected throughout Senegal demonstrated that transmission occurs with greatest frequency in the dry, sparcely vegetated north, decreasing to near zero in the south. Studies of the incidence of infection from regularly sampled, individually identified ungulates indicated that an epizootic occured during March-July 1988 at one of our study sites. This corresponded temporally with a large increase in the abundance of the two major *Hyalomma* species in that region. Virus isolation attempts from thousands of ticks sampled from these sites has yielded two strains of CCHFV, one each from pools of *H. impeltatum* and *Rhipicephalus guilhoni*. Engorged ticks removed from natural hosts are being tested for transovarial transmission of CCHFV.

Studies of human infection included serological and virological investigations. Spatial variation in the prevalence of human infection corresponded to that found in sheep, ranging from 10-20% in the north to less that 1% in the south. We report on a study of a fatal human case, that occured during the epizootic.

FOREWORD

Citations of commercial organizations and trade names in this report do not constitute an official Department of the Army endorsement or approval of the products or services of these organizations.

In conducting the research described in this report, the investigators adhered to the "Guide for the Care and Use of Laboratory Animals" prepared by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Animal Resources, National Institute of Laboratory Animal Resources, National Research Council (DHEW Publication No. (NIH) 86-23, Revised 1985).

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INTRODUCTION

Crimean-Congo Hemorrhagic Fever (CCHF), is one of a group of arthropod-borne viral zoonoses producing acute, sometimes fatal febrile and hemorrhagic disease. Symptoms initially involve the nervous system, and in severe cases progress to vascular disorders such as profuse diapedetic hemorrhages, brain edema, general malaise, and ultimately cardiac arrest. Human disease was first recognized from the Crimea, U.S.S.R. in 1945 (Chumakov 1945, 1947); shortly thereafter the viral agent was isolated from ticks (reviewed by Chumakov 1974). Crimean-Congo Hemorrhagic Fever virus (CCHFV), family Bunyaviridae, genus Nairovirus, was later found to be identical to that of "Congo virus" from Africa (Casals, 1969).

The distribution of CCHF now includes the southern U.S.S.R, central Asia, southern Europe, the Middle East, and the entire African continent (Hoogstraal 1979, Watts et al. 1988). In West Africa, Senegal and southern Mauritania have received attention as locations where CCHFV infects certain vertebrate and tick species. Initial observations by Chunikhin et al. (1969(a)) demonstrated evidence of domestic animal infections in particular vegetational-climatic zones of Senegal. Later, ticks from a Dakar, Senegal abattoir were studied and numerous strains of CCHFV were isolated (Robin & Le Gonidec 1972, Robin 1972, 1973, 1974, 1975). Similar recent observations of human and domestic animal sera identified other foci of transmission in various regions of Senegal and along the border with Mauritania. (Saluzzo et al. 1984, 1985(a), 1985(b), 1986, Camicas et al. 1986). Thus, foci of CCHFV infection have existed in this region for at least 2 decades; whether these foci persist with a low level of enzootic transmission, periodically erupt in epizootics, or are regularly reestablished by migrating reservoirs remains unknown.

At least 28 species of Ixodid ticks have been shown to be capable of supporting infection by CCHF virus; however, the importance of most of these ticks in maintaining the transmission cycle in nature is obscure. Many epidemiological reports implicate certain *Hyalomma* species that vary according to geographic region. *H. m. rufipes* is often associated with intense transmission in western Africa (Hoogstraal 1979). This association, however, is based upon sparse evidence of naturally acquired tick infection, combined with information on ecological associations among adult ticks. CCHFV has also been isolated from *H. truncatum*, and *H. impeltatum* two species equally abundant in our region. Surprisingly little is known about the ecology, population dynamics and host-associations of the immature stages of any of the *Hyalomma* species. The vertebrates that might serve as maintenance reservoirs of the virus are unknown, although circumstantial evidence suggests certain species. The importance of transovarial transmission

of the virus between tick generations in nature, relative to that of horizontal transmission, is also unknown. Thus, the manner in which the numerous individual components of the natural cycle of CCHFV interact is poorly understood.

The long-term objectives of our project are to investigate those variables that are ill-defined and probably important in the transmission cycle of CCHFV, and to integrate these new observations with existing knowledge in an attempt to develop a complex model capable of describing the enzootic cycle and the epidemiology of human disease. This report summarizes accomplishments during the second year of a projected three year effort.

Objectives

The objectives for the second year of the project included:

1. Continuation of longitudinal field observations of tick-host associations and seasonal patterns of tick abundance.
2. Systematic serosurvelance of human and animal CCHFV infection prevalence and incidence to illucidate environmental and vectorial correlates.
3. Enhancement of long-term studies of infection incidence among domestic and wild vertebrate and tick populations.
4. Development of laboratory models of CCHFV transmission and laboratory observations of infection using natural hosts.

The studies described in this document are being undertaken by a team of investigators comprised of scientists, and technicians from numerous institutions. The effort is one of collaboration, involving ecologists, entomologists, immunologists, epidemiologists, and virologists from a variety of different organizations (Table 1).

Study Sites

Our selection of potential long-term field sites was initially based upon information from previous research undertaken at the Institut Pasteur (Camicas et al. 1986, Saluzzo et al. 1985(a) and unpublished data). Details of the three sites chosen for prospective observations were previously reported (Wilson and Digoutte 1988). Here, we briefly describe the villages of Yonofere, Dahra and Bandia which we continued to study throughout this second grant-year.

Dahra, lies about 100 km. west of Yonofere and 200 km. east-northeast of Dakar (Fig. 1). The region is classified as Sahelo-sudanian savannah, a dry "thorn-brush" habitat dominated by grasses and widely dispersed trees, particularly *Acacia* spp. (Barral 1982). Rainfall occurs principally during

July through September and may vary considerably from year to year (Fig. 2), averaging about 500 mm. annually. Two different but comparable sites are under study. We are working inside the Dahra "Centre de Recherche Zootechnique" (CRZ), a national research station for domestic animal husbandry that is part of Senegal's "Institut Scientifique de Recherche Agricole. (This site is designated "Dahra-CRZ"). Outside that station we are working with cooperating resident herdspeople who provide us access to their animals and land (designated Dahra-village).

Yonofere is a small village of perhaps 1,000 year-round inhabitants occupying a few hundred widely dispersed huts about 300 km. (ca. 7 hours by vehicule) to the east-northeast of Dakar (Fig. 1). The habitat, rainfall and geo-climatic characteristics are similar to those in Dahra. Residents grow millet during the rainy season and herd sheep, goats and cattle year-round.

The site in Bandia is located about 20 km. from the Atlantic coast, some 60 km. southeast of Dakar (Fig. 1). On the edge of the Bandia forest, this more heavily vegetated region receives, on average, more rainfall (ca. 700 mm.); fluctuations in both daily and seasonal temperatures are somewhat modulated by the proximity to the ocean. This station has been the site of numerous previous studies of mammals (e.g. Hubert 1977), arthropod vectors (Camicas et al. 1970) and virus isolation (e.g. Digoutte 1985); this site offers an extensive history of observations for comparison.

In addition to these three prospective study sites, observations are occasionally made at other locations throughout the region, including southern Mauritania and western Mali.

This report describes past progress of ongoing research; thus, we write in the present tense. Results are reported for the second 12 months of study during the period beginning 1 January, 1988 and ending 31 December, 1988. Analysis of much of the data already collected is in progress, therefore not all results are presented in a quantitative form. Results are organized by topical questions divided into three sections: I. Tick Ecology and Behavior, II. Vertebrate-Virus Interactions, and III. Virus Transmission.

1. TICK ECOLOGY and BEHAVIOR

Adult Tick Seasonal Activity

One objective of our project is to determine which species of tick(s) and vertebrate(s) are important in CCHFV transmission. The agent of CCHF is unusual among zoonotic arboviruses: the number and ecological diversity of potential vectors and vertebrate hosts with which it is associated is enormous. In addition it is found in a variety of faunal regions throughout the world. Previous studies have implicated various 2-host or 3-host African ticks, either by inference or evidence of infection (reviewed by Hoogstraal 1979); these include 5 species of the genus *Hyalomma*, and one each of the genera *Amblyomma* and *Rhipicephalus*. Among our study sites, 4 of the *Hyalomma* and 2 of the *Rhipicephalus* species are present, as is *Amblyomma variegatum* (Table 2).

In order to characterize the temporal, spatial and ecological patterns of activity and population density of these ticks and their hosts, prospective observations at the 3 major study sites have been continued. The research described below is being undertaken in collaboration with Drs. Jean-Paul Cornet and Jean-Louis Camicas.

"Au Hasard" Observations. A herd of sheep is chosen by chance encounter, in Yonofere and Dahra-village, and 10 randomly selected individuals are carefully examined for the presence of ticks. Particular attention is focused on the tail, perianal and abdominal regions, feet and the head (ears and eyes). All ticks are removed with forceps and stored for later identification and virus isolation. Five herds are examined at each site about every month. Samples were first taken beginning in May 1987 and have continued to the present More than 1,500 sheep have been thusly examined. From these animals more than 10,000 adult *H. truncatum*, *H. impeltatum*, *H. marginatum rufipes*, *H. dromedarii*, *Rhipicephalus evertsi*, and *R. guilhoni* have been sampled. Three species dominate: *H. truncatum*, *H. impeltatum*, and *R. guilhoni*.

The temporal pattern for *Rhipicephalus guilhoni* was seasonal, with maximal activity during and just after the rainy season (Fig. 3). These results correspond with those from other sites, and are consistent with a well-defined and limited period of adult activity for other species of the genus. (Although *R. guilhoni* has not been implicated previously as a potential vector of CCHF virus, we recently isolated virus from a pool taken in Yonofere [see below].)

Seasonal activity for both of the dominant *Hyalomma* ticks was different than that of *R. guilhoni*. *Hyalomma truncatum* and *H. impeltatum* were extremely abundant during January through May 1988; during the following months this activity subsided (Fig. 4). Adults of both species appear to be more or less

active throughout the year, with the observed "peak" of activity suggesting either favorable environmental conditions, and/or a real increase in abundance. Observations continue in an effort to explain correlations with fluctuations in climate and immature tick host abundances. These results, however, are consistent with other studies on the seasonal activity of potential vectors, and permit us to hypothesize a correlation between adult *Hyalomma* population fluctuations and epizootic transmission (reported below).

Tick burden and infection rate. Another source of information on adult tick abundance is derived from animals which are part of our systematic serosurveillance. At the Dahra-CRZ, cattle that permanently reside there are sampled monthly during periodic captures undertaken by personnel of the research station; while these animals are restrained, we search carefully for ectoparasites as described above. Results from these observations will permit comparisons of the seasonal dynamics of ticks on cattle and sheep which are non-migratory and which inhabit another region where CCHFV circulates. Furthermore, the heritage, herd group, date of birth and history of pasture use is known for each individual cow, permitting more detailed analyses as questions arise.

Sentinel Animals. Information on adult tick abundance is being gathered from privately-owned sheep and cattle in Yonofere and Bandia. These animals have been tagged but are maintained as part of their original herd. About 12 goats and 2 cattle in Bandia and nearly 100 sheep from Yonofere are being studied at regular intervals. Such observations permit comparisons with a somewhat different ecological region (Fig. 1). Repeated observations of the same animals allow us to consider individual differences in infestation rates.

Results from Bandia for *Rhipicephalus guilhoni* and *Hyalomma truncatum*, the two predominant species, suggest similar activity cycles as those found for these species in Dahra and Yonofere. *R. guilhoni* was active just after the end of the rainy season (Fig. 5) as observed at our Ferlo sites. *H. truncatum*, more abundant on cattle than goats, was usually present but appeared more active during and just after the rainy season (Fig. 6 a,b). Interestingly this tick was <u>not</u> extremely active during January and the months following as was observed in the Ferlo. *H. m. rufipes* was recovered in moderate numbers on cattle in Bandia, and showed a seasonal pattern similar to that of *H. truncatum* (Fig. 6c). Sufficient variations in vegetation, host movement or density might occur, over the scale of tens to hundreds of km., to produce significant differences in local vector abundance

Larval and Nymphal Population Ecology

The feeding pattern for immature stages of most of the tick species under study differs significantly from that of the adult stage. Classically, larvae and nymphs of these species feed on birds and small mammals, and are rarely found on the ungulates that serve as hosts to adults. In order to investigate further the host associations and population dynamics of the immature stages of these potential vectors, we have undertaken studies of the birds and small mammals at our long-term field sites.

Immature ticks on birds. Observations continue in an effort to determine the role of birds as hosts to larval and nymphal ticks, as well as to characterize seasonal activity and densities of the ectoparasite. About monthly, birds are captured or shot at Yonofere using Japanese mist-nets, a locally constructed ground net or a 32-gauge shotgun. Each bird is carefully examined by blowing air through a tube to seperate the feathers and thereby view the skin. Attached larvae and nymphs are placed into live vials until they have molted (thereby facilitating identification), or are stored in 70% ethanol. Organs and blood of killed birds are stored at -70° C. for later study.

Of nearly 500 birds examined at Yonofere, 12 (2.4%) harbored 32 ticks (Table 3). Most ticks were immature *H. m. rufipes* (18 larvae , 4 nymphs), and there was 1 larval *H. truncatum*. The majority of ticks were recovered during a few months at the end of and following the rainy season; variation in number and species of birds examined throughout the year prevents us from making statement about seasonality. Seven species of birds were found infested on at least one occasion including: 3/13 Red-beaked Hornbills (*Tockus erythrorhynchus*), 3/6 Long-Tailed Glossy Starlings (*Lamprotornis caudatus*), 1/7 Chestnut-bellied Starling (*Spreo pulcher*), 1/11 Slender-billed Weavers (*Ploceus luteolus*), 2/5 Vitelline Masked Weavers (*Ploceus velatus*), 1/10 Village Weavers (*Ploceus cucullatus*) and 1/83 Grey-headed Sparrows (*Passer griseus*). Again, the temporal pattern of these observations makes statments about the importance of particular species difficult. As previously noted, however, ground feeding birds seem to be more often infested.

The role of birds in the reproductive cycle of *Hyalomma* ticks remains obscure. Any estimate of their importance as hosts to immature ticks depends both on the rate of ectoparasitization per species and the density of that species. The paucity of immature ticks that were found feeding on birds suggests that other hosts may be more important. Although it is much to early to consider our results as yet accurate, it would appear that proportionatly few *Hyalomma* immatures feed on birds. Observations such as these will continue in an effort to better describe seasonal

activity patterns of larvae and nymphs, their pattern of infestation of bird hosts, as well as the densities of these species.

Immature ticks on small mammals. Immature *Hyalomma* ticks are known to feed frequently on small mammals. Ongoing studies that complement those on birds continue. At Yonofere and Bandia, modified Manufrance live-capture traps, baited with peanutbutter, are placed 10 meters apart in lines located near suitable habitat. About 120 and 140 trapnights per month produce rodents at Yonofere and Bandia, respectively. Small mammals are carefully inspected for ectoparasites by blowing against the fur to view the skin surface. Attached ticks are removed with fine forceps and kept alive as described for birds; alternatively, small mammals are held for 7 days in cages over water where engorged ticks that dettach are recovered.

The two sites differ both in the number of small mammals captured, and the intensity of immature tick infestation. At Yonofere, very few rodents were captured. From a total of 71 small mammals examined, 18 immature ticks of the genus *Hyalomma* were recovered: 12 *H. truncatum* (2 larvae, 10 nymphs) and 6 *H. marginatum rufipes* (all nymphs) (Table 4). The most frequently trapped small mammal was *Mastomys erythroleucus*, through it was not heavily parasitized. The few hares (*Lepus whytei*) examined were often parasitized but with a few ticks.

In contrast, a similar trapping effort at Bandia, produced 353 small mammals comprising 4 species that harbored at least 100 *Hyalomma truncatum* or *Rhipicephalus guilhoni* (Table 5). In total we recovered 7 larval and 21 nymphal *H. truncatum*, as well as 9 larval and 36 nymphal *R. guilhoni*. Three-quarters of the small mammals examined were *Mastomys erythroleucus* although the distribution of *H. truncatum* was roughly proportional to capture rates among the various host species. The period of greatest activity for *H. truncatum* again appeared to occur at the end of and just following the rainy season. That for *R. guilhoni* was during January and February.

The difference between the two sites in apparent rodent density and immature tick burdens remains enigmatic. Even fewer rodents were captured this year at Yonofere and immature ticks were rare. At Bandia rainfall and vegetation are generally greater yet there appears to be a similar or greater burden of adult ticks on domestic ungulates at Yonofere as at Bandia. How can Yonofere's sparse small mammal population, harboring relatively fewer immature ticks, produce an apparently abundant population of adult ticks? This represents an unresolved question that is fundamental to our understanding of the population dynamics of CCHF vector ticks, and one which will continue to receive attention.

Rodent Burrow Ecology

In order to further investigate habitats where ticks are found, we continued excavations of rodent burrows in Bandia and Yonofere. In collaboration with Dr. Cornet, randomly selected rodent burrows were examined: six new burrows were excavated monthly at both the Bandia and Yonofere sites. The burrow entrances were opened with a small shovel and other such tools, and the loosened soil was aspirated by a large "vacume" constructed from a gasoline-powered leaf blower. A series of filters separated larger rocks while permitting fine sand to pass thereby trapping ticks and other small arthropods. All tunnels and chambers were opened and the contents aspirated. Based on the structure of the burrow, and the size and shape of fecal pellets, the rodent species that inhabited the site was identified.

Few Ixodid ticks were recovered and observations were made only through August 1988 in Bandia, and April 1988 in Yonofere. A total of 60 burrows were examined including those of *Mastomys sp.* (31), *Taterillus sp.* (20), *Arvicanthis niloticus* (8) and *Xerus erythropus* (1). Most of these burrows contained the Argasid tick *Ornithodoros sonorai*. Only one female *Rhipicephalus guilhoni* was found suggesting either that few nymphal ticks detach therein or that newly molted adults rapidly exit these burrows.

II. VERTEBRATE-VIRUS INTERACTIONS

In addition to observations on tick infestation patterns of various hosts, we have continued studies on other variables that contribute to the transmission dynamics Crimean-Congo Hemorrhagic Fever virus. The population densities of various hosts, for example, influence the importance of a given level of infestation. Similarly, the efficiency of transmission, host inhibition of vector feeding, or pathogenic effects on host or vector demography could affect the interactions that ultimately form the conditions of transmission.

Prevalence of Infection in Vertebrates

The prevalence of CCHFV infection in vertebrates is being estimated in various sites to indentify the spatial and temporal distribution of infections as well as the vertebrate species most likely to be important in the transmission cycle. Blood and tissue samples are being obtained at all three main ..udy sites. In addition, samples are occasionally made at other sites throughout Senegal, Mauritania, Mali, and The Gambia. Blood samples are taken from domestic ungulates (primarily sheep, goats and cattle) as well as from birds, small mammals, dogs and other vertebrates. (Organs are also sampled from animals that are killed or die.) Blood is allowed to clot and then held at +5-10° C for 1-4 days after which the serum is removed and stored at -70° C. A CCHFV-antibody capture ELISA, developed by Dr. Thomas Ksiazek and colleagues at USAMRIID is being used by Dr. Bernard LeGuenno here at the Pasteur Institute to test these sera.

Blood samples are centrifuged and sera removed and stored at -20° C. Sera are diluted (usually 1:400) and tested against a reference virus strain, a West African strain recently isolated from a patient in Rosso, Mauritania (DKR 49919), and a control antigen (crude suckling mouse brain). Hyperimmune mouse assitic fluic, coated on 96-well plates, is used to catch the antigen, and the sera are then tested. Differences in the Optical Density (OD) are measured and recorded by an automatic reader (Multiscan MCC340, Flow Laboratories) coupled to a microcomputer (Amstrad PC1512). By repeating interations of the distribution of OD values, we determine the mean of the population of negatives. Sera are considered positive for IgG antibodies if the OD is greater than 3 standard deviations above the mean of negatives.

Spatial Distribution of CCHFV throughout Senegal. In collaboration with Dr. Marc Guillaud of France's "Institut d'Elevage et de Medecine Veterinaire des Pays Tropicaux" and Dr. D. Desoutter of the "Institut Senegalais de Recherches Agricoles" (ISRA) sheep sera collected from villages throughout Senegal were tested to identify the prevalence and the spatial distribution of CCHFV transmission. Sera were drawn from sheep throughout Senegal as part of a separate study initiated by ISRA. Of 80 administrative districts

throughout the country, 22 were chosen at random for testing. The number of animals sampled in each district was calculated at 1/50,000 resident sheep. Sheep were bled at random from herds in local villages, typically 10 or 20 individuals per village. Another distant village was then selected until the predetermined *per capita* sample size was achieved. Between November 1987 and February 1988, sheep were sampled from each of 66 herds in 22 districts from 7 of Senegal's 8 Regions. The sex and age by dentition were recorded for each animal. Based on dental examination, sheep were placed into one of four age catagories from 1 to 4 or more years old.

A total of 10.4% of sheep was found positive for anti-CCHF virus IgG antibodies among the 942 sera tested from 66 villages in 7 Regions (Table 5). The sample size tested from each village varied from 1-31 (mean = 14.3 $\pm$ 16.3) and was independent of IgG antibody prevalence (r^2=0.013, N=66, p=0.36) sexratio (r^2=0.008, p=0.48) and age (r^2=0.03, p=0.17). Thus, analyses among individual sheep were performed. The golbal prevalence rate of 7.1% for male sheep (N=156) did not differ from that of 11.3% for females (N=773) (X^2=2.006, d.f.=1, p=0.16). Furthermore, male and female prevalences were not different when examined separately in each of the 4 age categories or within each Region (all p-values > 0.10).

The prevalence of anti-CCHFV IgG increased with age. Only 2.1% of the youngest animals (<=1 year) tested positive, whereas 18.2% of the oldest sheep (4+ years) were once infected (Fig. 7a). Prevalence increased with age for both male and female sheep, and in a similar manner in those Regions where infection was observed (Fig. 7b). Similarly, comparison of village rates using multiple stepwise regression of mean age, sex ratio and number sampled against CCHF antibody prevalence rates revealed only a positive correlation with age (r^2=0.10, n=66, p<0.001). Older sheep exhibited a higher CCHFV antibody prevalence.

Evidence of CCHFV circulation varied among Regions and villages (Table 6). Average antibody prevalence among the 22 administrative districts appeared highest in northern Senegal and decreased to nil in the southern part of the country (Fig. 8a). We divided the country into 5 phyto-geographic "zones" based upon vegetation and climatic variables (Ndiaye 1983) and compared results among these zones. Sheep from the northern-most, driest "sahe'ian" zone averaged 75.7% seropositivity, a prevalence rate which decreased to 0% in the southern, moister "sudo-guinean" and "sub-guinean" zones (Table 7). Similar analyses comparing geological formations, soil types, altitude, and sub-surface water revealed no relationships. Because rainfall alone contributes substantially to the structure of phytogeographic zones, we compared CCHFV antibody prevalence rates grouped according to mean annual rainfall (Leroux 1983) of their village (Fig. 8b). Antibody prevalence consistantly increased

with decreasing annual rainfall. CCHFV transmission apparently occurs with greatest intensity in drier, more sparcely vegetated regions.

Point Prevalence among Cattle, Sheep and Goats. Domestic animals are being bled in and around the Dahra CRZ to estimate the local prevalence of infection and to correlate this with variation in tick abundance and other variables. During 1988, samples from 377 cattle, and 1,126 sheep and goats were tested. Among 20 - 30 cattle sampled monthly at the Dahra CRZ IgG antibody prevalence varied considerably from 5% to more than 60% depending on the group sampled; very little IgM was apparent. Prevalence among sheep and goat sub-samples was similarly variable until June when we began censusing the entire flock at Dahra-CRZ. Prevalence of IgG seropositivity generally rose during the year, and now remains at more than 40% of the entire group. IgM antibody prevalence has declined but is still detectable in about 5% of animals. In contrast, IgG prevalence among individually identified sheep at Yonofere has remained low at 4-14% depending on the herd and time of year. Interestingly, herd prevalence has not changed significantly with the introduction of newbornes.

Maternal Transfer of Antibodies to Offspring

In order to examine the rate of maternal antibody transfer to young sheep and cattle, mother-offspring pairs are being bled every 2-3 months in Yonofere and Dahra. Sheep at Yonofere have been bled for as long as 18 months, many with young now 10 months old. Preliminary analysis of the appearance of IgG antibodies among infants whose mothers are seropositive suggests that at least 80% of neonates have detectable IgG. (The evidence for such transfer is even stronger for anti-Rift Valley Fever virus IgG, as nearly th ee-quarters of about 50 such sheep are seropositive.) A similar effort is underway using individually identified cattle and sheep at the Dahra CRZ. Although IgG antibodies have been detected, we have not yet titred these sera. As more samples are obtained, we will attempt to quantify the rate of diminution of IgG in both mother and orfspring.

Incidence of Infection in Sheep and Goats

In an attempt to describe the incidence of new CCHFV infection acquired under natural conditions, and ultimately relate this to the seasonal dynamics of various *Hyalomma* species, we are periodically monitoring a group of individually-identified, privately-owned sheep in Yonofere. Numbered eartags have been placed on over 100 sheep to date. In addition, we are monitoring the antibody status of more than 300 individual sheep and goats every three months at the Dahra field station. A total of 1,126 serum samples from Dahra and 391 from Yonofere were tested during 1988.

At the Dahra field site, sheep IgG prevalence remained low and IgM prevalence was undetectable through February of this year when increased evidence of transmission was observed (Fig. 10). During the next several months IgM antibody prevalence increased and then declined, after which we observed an increase in IgG prevalence. In all, roughly two-thirds of the sheep were infected during a period of increased adult *Hyalomma* activity (Fig. 4a,b). Concurrently, numerous sheep were sick and died. Two of 4 sheep bled because they were ill exhibited high titre IgM antibodies. CCHF virus was isolated from a pool of male *H. impeltatum* ticks removed from one of these two sheep.

No such epizootic was observed at Yonofere, despite the fact that adult *H. truncatum* abundance rose to a high level at the same time (Fig. 4c). The explanation for this remains unclear though we hypothesise either a) that *H. impeltatum*, but not *H. truncatum* was most important in transmiting CCHFV in Dahra, or b) that tick infection rates were somehow enhanced at Dahra. Results from isolation attempts will help us to explain the observed epizootic. Prospective observations continue.

Prevalence of Infections in Humans

Human serological studies, though less systematic and thorough, have suggested a geographic pattern of human CCHFV transmission which is similar to that arising from studies of sheep. Although preliminary, these observations suggest a similar north-to-south gradient in infection.

Sera collected from 8 different sites during the previous 3 years have been tested. Among the adults sampled, less than 1 percent of people living in 3 southern Senegal sites were IgG positive (Fig. 9). Three north central sites demonstrated moderate rates of past infection ranging from 3 to 20 percent. Further north, in 2 Mauritanian border towns, blood samples which were kindly provided by Dr. Elizabeth Manus of the Yale Arbovirus Research Unit and Dr. Alain Jouan showed antibody rates of about 5 to 10 percent. Here again, the force of infection among humans is greatest in the northern, drier regions where we have found a surprisingly large percentage of people to be at risk. More systematic, prospective serological sampling is underway in an effort to determine annual incidence in different regions.

Studies of Human Disease

Human cases of Crimean-Congo Hemorrhagic Fever have been recognized from at least a dozen countries distributed over three continents. Since 1956, 69 human cases of CCHF have been studied from sub-saharian Africa, mostly in Southern Africa (e.g. Watts et al. 1988, Swanepoel et al., in press). Knowledge of the epidemiology and viral ecology of CCHF in Africa is based largely on studies of cases and occasional outbreaks in South Africa (Watts et al. 1988). From West Africa, only two human cases have been documented, one of which was confirmed by virus isolation (Saluzzo et al. 1984, 1985a). Consequently, few data are available on human disease and CCHF virus ecology remains unknown for this part of the world. We undertook a study, directed by Dr. Jean-Paul Gonzalez, of several virological and serological components of a fatal human case of CCHF diagnosed in southern Mauritania in May 1988.

Serum samples. A hospital-based survey in the northern Senegal border town of Rosso, Mauritania (Fig. 11) lead us to select patients on the basis of a severe infectious syndrom with suspected viral Hemorrhagic Fever. Blood samples were drawned by veinupuncture using the Vacutainer system. After centrifugation sera were kept at 4° C for at most 10 days and then processed at the Pasteur Institute for virus isolation and/or serological study.

Environmental and epidemiological observations were conducted in two nomadic camps in which hospitalized persons with suspected or confirmed CCHF infection lived. Blood samples were drawn from human and domestic animals; the latter were investigated for tick parasitism. Sera drawn from 910 sheep, as part of a study on RVF, were also tested.

Virological and immunological observations. Virus isolation was attempted by intra-cerebral inoculation into day-old suckling mice. Human and animal serum samples, and ground monospecific tick pools were processed for virus isolation. Virus identification was made by indirect immunofluorescent test using polyclonal and monoclonal antibodies and by complement fixation. The IgG ELISA test used in this study was described above. IgM antibodies were detected by an immunocapture ELISA. Presence of antigen was detected in sera samples by an antigen capture ELISA.

During May 1988, 6 of 8 selected patients from the Rosso hospital who exhibited viral hemorrhagic fever symptoms showed an elevated IgG titer against CCHF antigen (Table 8). Three of them died. In only one case were IgM antibodies detected. This 16 year-old woman was admitted to the hospital with vigil coma, fever and jaundice but no sign of hemorrhage; she died 20 hours following hospitalization (O. Bioux, pers. comm.).

Intra-cerebral inoculation into day-old mice of a blood sample drawn upon hospital admission produced a virus which was identified as CCHF by imunofluorescence, using both polyclonal and monoclonal antibodies. The identity of this isolate was then confirmed by complement fixation at the Pasteur Institute's WHO Collaborating Center for Reference and Research for the Arboviruses. No immune complex was detectable nor was free antigen found in the sera.

An epidemiological study conducted in the villages of Ndeyboussat, Thioury and Mbalal showed that several family members of the hospitalized cases were seropositive, with the overall antibody prevalence being 36% (Table 9). A retrospective study of a limited number of patients admitted to the Rosso Hospital during May - July, 1988 showed that more than one-third of these people were IgG positive (Table 10). One patient admitted during May exhibited class M antibodies.

Domestic ungulates from two of these three villages were examined for the presence of anti-CCHFV antibodies and ticks. On the whole, roughly half of these animals were parasitised by adult *Hyalomma impeltatum* or *H. dromedarii*, and one-third exhibited detectable IgG antibodies (Table 11).

A systematic survey of sheep from a large region of southern Mauritania demonstrated IgG antibody rates ranging between 5 and 40 percent (Table 12). Furthermore about 7% of these sheep exhibited IgM antibodies. These later results suggest a period of epidemic transmission during March through July, a time which corresponds with anticdotal reports of an intense infestation of ticks and our observation of such.

The human case(s) of Crimean-Congo Hemorrhagic Fever occured during the period when we observed an intense epizootic in Dahra, 100km to the south. Adult *Hyalomma* spp. ticks also were extemely abundant there at that time. Antibody prevalence in the villages from which hospitalized cases came was higher (36.4%) than that observed in the August 1988 serosurvey (11.1%) of 177 people tested (Fig. 9). Serological studies performed on 82 patients entering the Rosso hospital in October 1987 with an infectious syndrome during the epidemic of RVF produced a CCHFV seroprevalence of 4.5% (B. LeGuenno, pers. comm.). These results suggest a recent period of elevated CCHFV transmission. Studies undertaken in South Africa following the first identified case of CCHF there gave a prevalence of 0.2% (1/448) among hospitalised patients and 1.5% (17/1108) among local farmers In sum, there appears to be as much or more transmission of CCHFV in our study sites as in other similarly monitored areas and an epidemic/epizootic did occur in northwestern Senegal and southwestern Mauritania during early 1988. Continuing prospective observations should reveal other such periods of increased transmission.

III. VIRUS TRANSMISSION

Prevalence of Virus in Ticks

In order to characterize the magnitude of infection in vectors, thereby contributing information to calculations of transmission potential, we have been collecting feeding ticks which then are analysed for the presence of CCHFV infection. Dr. Camicas, who collects material from Bandia, identifies and pools these ticks as well as those from Yonofere and Dahra. Ticks pooled according to species, sex, individual animal or herd are held at -70°C until testing, at which time they are ground for virus isolation. Suckling mouse innoculation is used for detection of virus. Other studies of tick egg infection are being undertaken with Drs. LeGuenno and Gonzalez, as well as researchers from USAMRIID's Disease Assessment Division, use an antigen-capture ELISA to test for the presence and abundance of CCHF virus. In collaboration with Marie-Armande Calvo, the identity of viruses from ticks or eggs is confirmed using a CF test following mouse passage.

Three types of tick collections are being undertaken: "en masse" from cattle and sheep, from randomly selected sheep being studied for evidence of tick activity patterns and from individually identified sheep, cattle and goats being bled for evidence of antibodies and virus. About 1,000 ticks are being collected monthly for virus isolation by herdspeople from Yonofere and surrounding villages; they are given tubes into which they place ticks that they have removed from their animals. Ticks from 100 sheep sampled in Yonofere and Dahra-village each month to determine tick seasonality are also tested for the presence of virus. In addition, sheep and cattle at the Dahra CRZ, sheep in Yonofere, and goats and cattle in Bandia which are under study for the incidence of new CCHF infection are deticked during bleeding. These ticks also are being tested for virus.

During 1988, sheep and cattle in Yonofere have yielded more than 15,000 *Hyalomma truncatum*, *H. impeltatum*, *H. marginatum rufipes*, *H. dromedarii*, *Rhipicephalus evertsi*, and *R. guilhoni*. Of more than 700 pools thusfar identified, 524 have been tested and 31 have produced arboviruses (Table 13). Most of these have been shown to be Wad-Medani virus or a closely related strain. However, CCHF virus was isolated from a group of 20 male *Rhipicephalus guilhoni* taken from sheep in Yonofere. Although other *Rhipicephalus* species have been shown to be infected, this is the first reported isolation of CCHFV from *R. guilhoni*.

Similar results were obtained from Dahra where about 6,000 ticks have been sampled. Of the 251 pools tested, 5 have produced arboviruses; four were Wad-Medani. We also isolated CCHF virus from a pool of 17 male *H. truncatum* taken

from a sheep inside the Dahra CRZ. Interestingly, this sheep was "sick" at the time and demonstrated high titer anti-CCHFV IgG antibodies.

In Bandia, more than 2,000 ticks were collected during 1988 and about 140 tick pools have been tested. Crimean-Congo Hemorrhagic Fever virus has not yet been isolated, although other arboviruses have appeared. (Evidence that CCHFV circulates actively comes from the presence of IgM among a few sentinal animals.)

Ticks collected from other miscellaneous sites in Senegal, Mauritania and Mali are also being tested for virus. Bhanja virus was confirmed from a pool of *H. dromedarii* taken from southern Mauritania. These studies are continuing in an effort to estimate the minimum infection rates of various tick species and to correlate this with vector density and vertebrate infection rates.

Transovarial Transmission

Circumstantial evidence suggests that transovarial transmission (TOT) of CCHFV occurs in nature, but the extent, conditions and importance of such transmission remain unknown. Studies of vertebrates suggest that they rarely express intense or sustained viremia. Furthermore, certain tick species have been shown capable of TOT in laboratory tests. To investigate the relative importance of vertical versus horizontal transmission, we have begun observations designed to determine the TOT rate for CCHFV in northern Senegal. Feeding ticks are removed from cattle, sheep and camels in our study sites and placed in individual vials in the laboratory as described above. Following egg-laying, the adult tick's corpse is frozen at -70° C, as are a portion of the eggs. Using an antigen capture ELISA mentioned above, we are testing for the presence of CCHFV in both the parent tick and it's eggs. Verification of ELISA-positive ticks or eggs testing will be made following mouse passage using a Complement Fixation test. Furthermore, we are attempting to use larvae that emerge from CCHFV-infected egg batches to calculate the percentage of eggs infected transovarially, and to determine if transstadial transmission of TOT infected eggs occurs. More than 1,500 ticks comprising 4 species of *Hyalomma* and 2 species of *Rhipicephalus* thusfar have been returned to the laboratory in this ongoing effort. Two egg batches have been tentatively identified as infected by CCHF virus.

Horizontal Transmission

The capacity of a vector to transmit a particular pathogen depends upon variables such as frequency of vector feeding, time between blood-meals, diversity of host species utilized, extrinsic incubation time for the pathogen, and efficiency of pathogen transmission to the host. A multitude

of complementory factors influence the hosts ability to reinfect the vector. Certain of these components can be studied under field conditions and we have begun observations to this end.

Results from observations on tick infestation rates, infection rates of these ticks, and serology of their hosts will be examined as an ensemble in an attempt to correlate differences in rates of infection that might explain intensity of transmission. Analyses such as these have guided subsequent experimental studies that were begun late this year. In collaboration with Drs. Gonzalez and Cornet, *Mastomys erythroleucus*, domestic chickens and rabbits have been innoculated with CCHF virus to determine the magnitude of viremia and development of antibodies.

Preliminary results with *Mastomys erythroleucus* indicate that IgM antibodies are detectable at about day 6 post-infection, and that viremia appears at about day 7 or 8. A similar pattern seems to occur with laboratory rabbits. Immature *Hyalomma* ticks are being fed on these hosts in an effort to determine the rate of horizontal infection. Observations are planned for other potential natural hosts.

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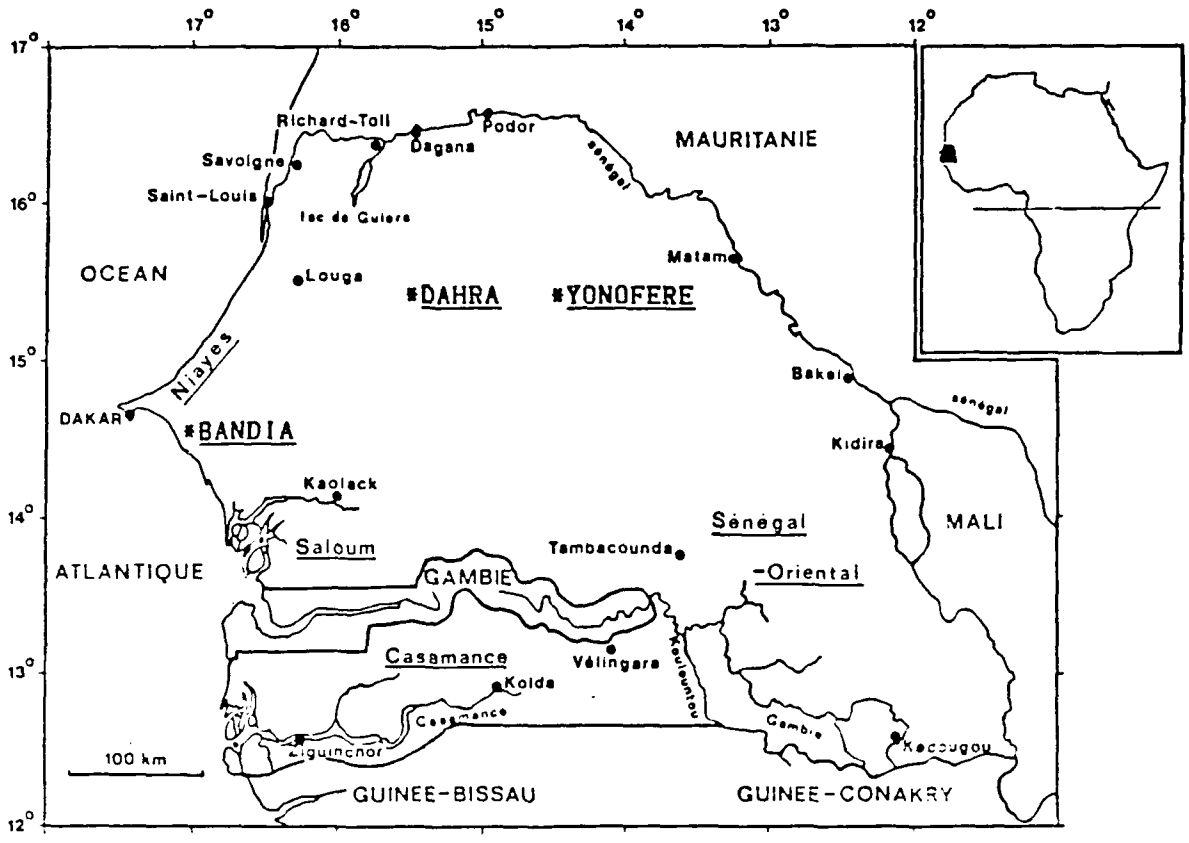


Figure 1. Map of Senegal indicating the principal geopolitical regions (underline), larger cities (dot), and three major study sites (asterisk, underline) discussed in this report.

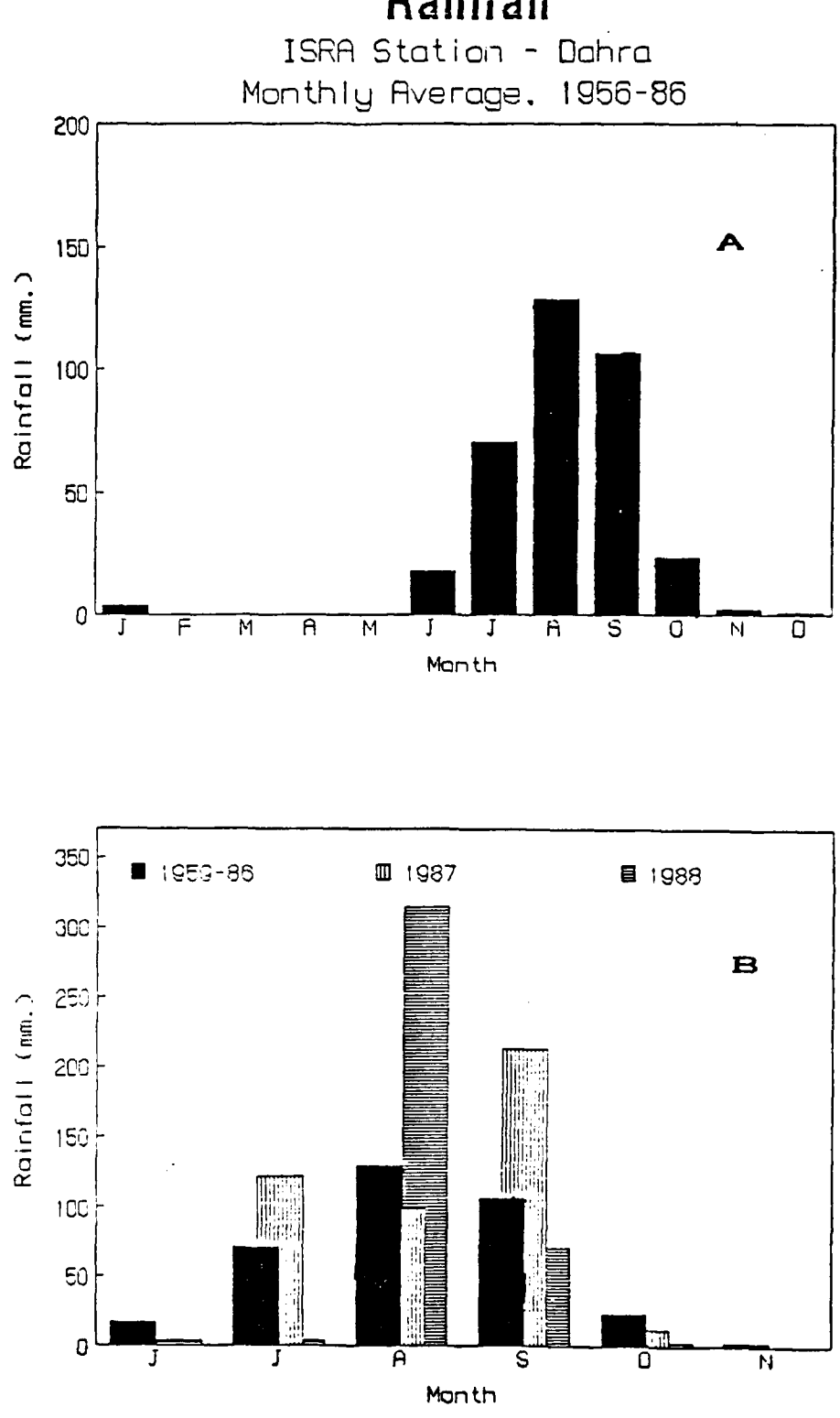


Figure 2. Average monthly rainfall (A) during 1959-1986 at the Dahra Research Station, and (B) total monthly rainfall during 1987 and 1988 at that site.

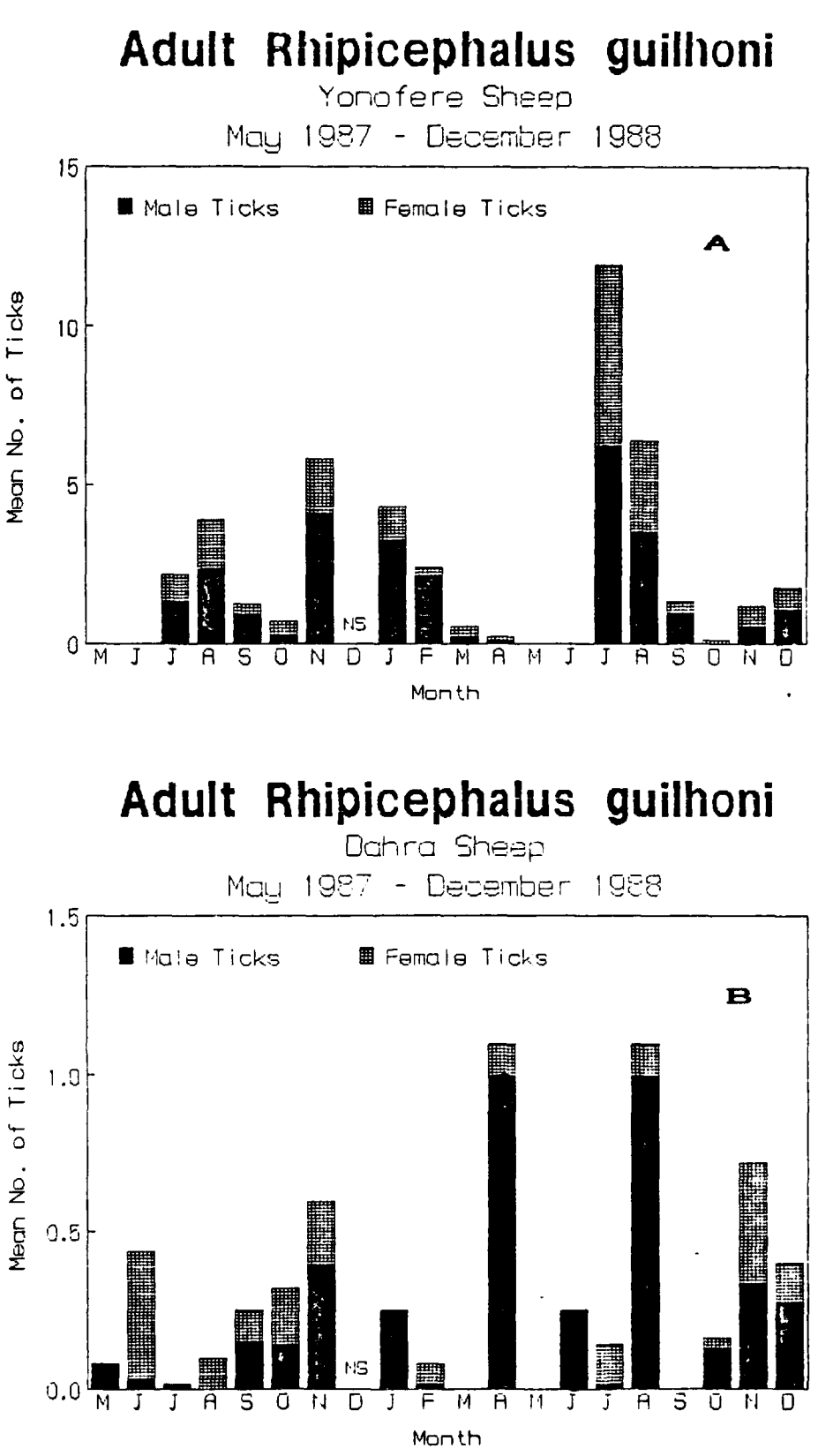


Figure 3. Mean number of adult *Rhipicephalus guilhoni* per month from sheep in (A) Yonofere and (B) Dahra, Senegal during May 1987 through December 1988.

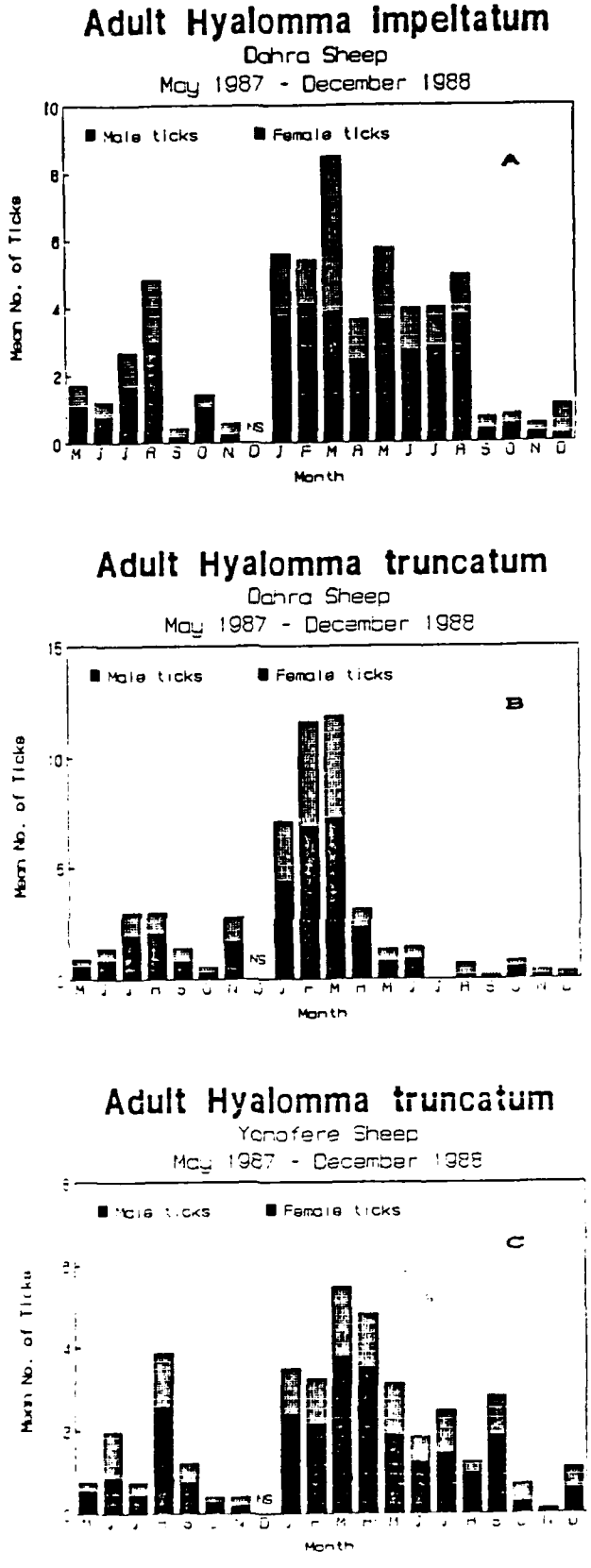
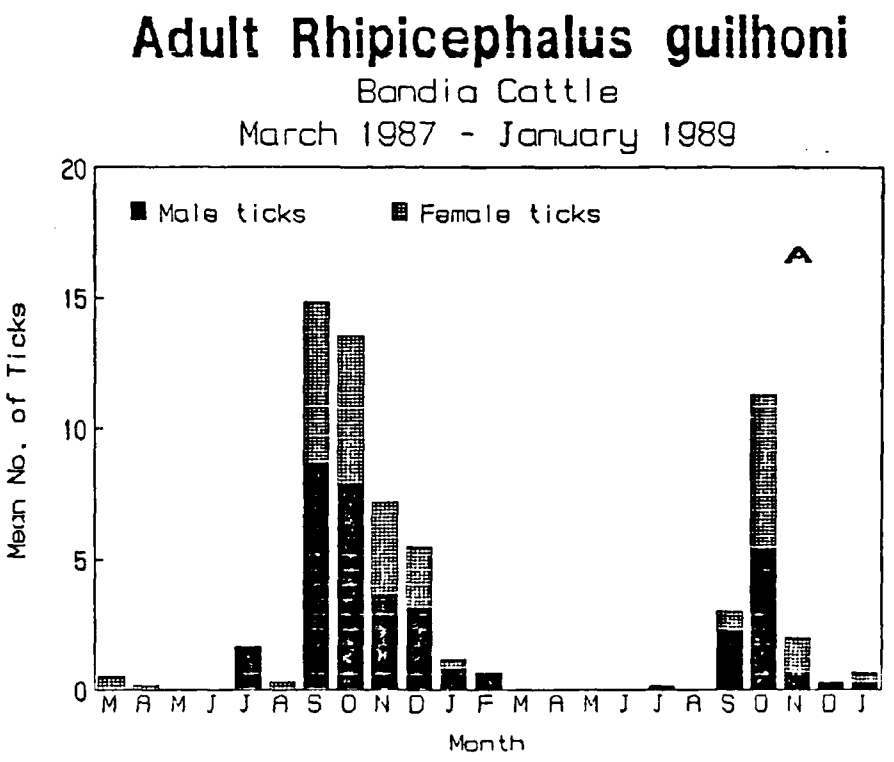


Figure 4. Mean number of adult *Hyalomma* ticks per month from Dahra and Yonofere, Senegal from sheep sampled monthly during May 1987 through December 1988: (A) *H. truncatum* and (B) *H. impeltatum* from Dahra and (C) *H. truncatum* from Yonofere.



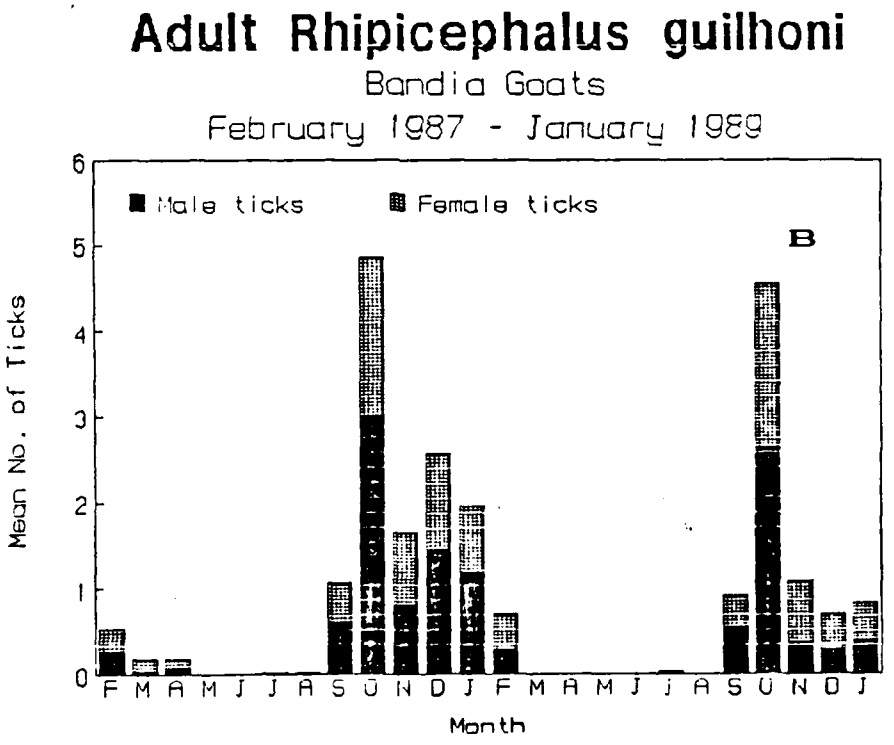
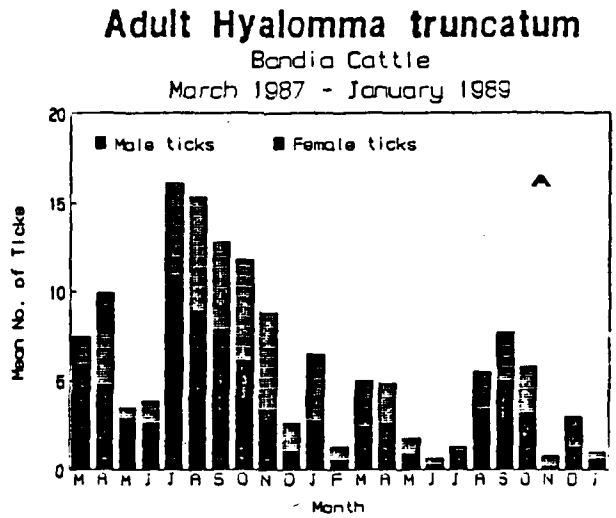
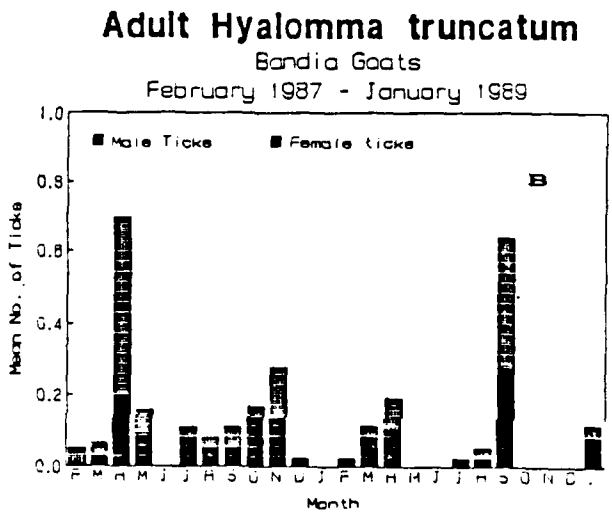


Figure 5. Mean number of adult *Rhipicephalus guilhoni* per month from (A) cattle and (B) goats in Bandia, Senegal during March 1987 through January 1989.





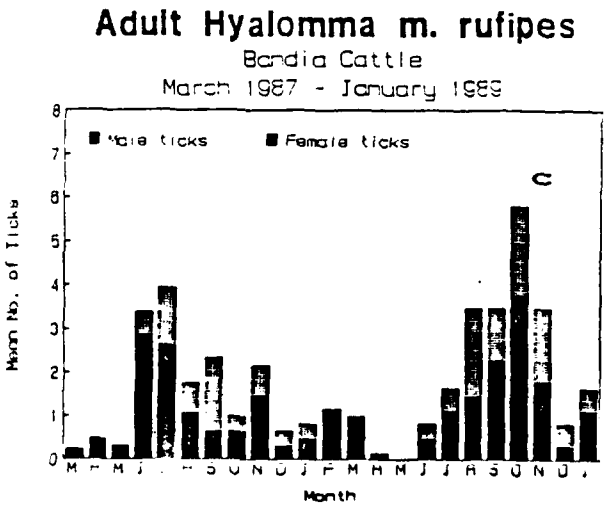
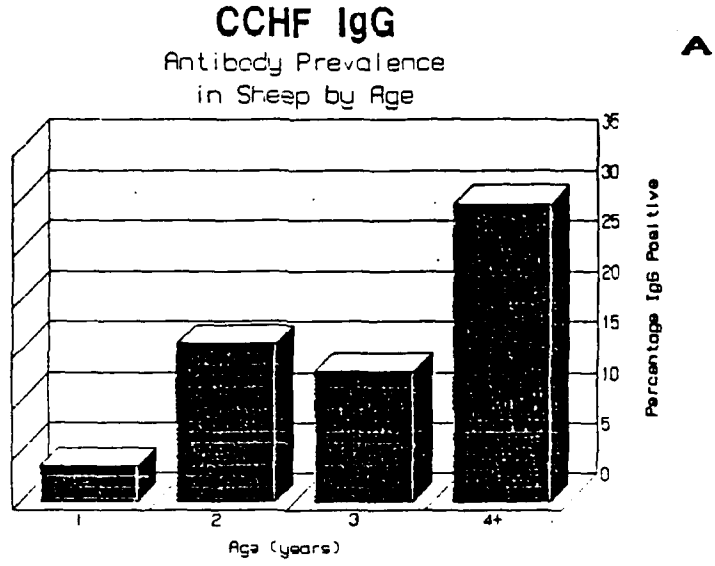


Figure 6. Mean number of adult *Hyalomma* ticks per month from Bandia, Senegal sampled monthly during March 1987 through January 1989: (A) *H. truncatum* on cattle, (B) *H. truncatum* on goats and (C) *H. m. rufipes* on cattle.



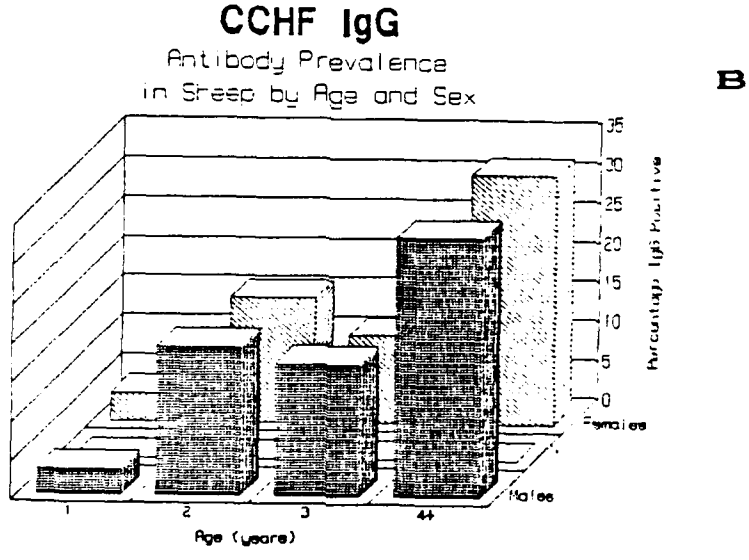


Figure 7. Prevalence of class G antibodies against CCHFV among 942 sheep sera tested from 66 villages throughout Senegal during November 1987 through February 1988 divided by (A) age and by (B) age and sex.

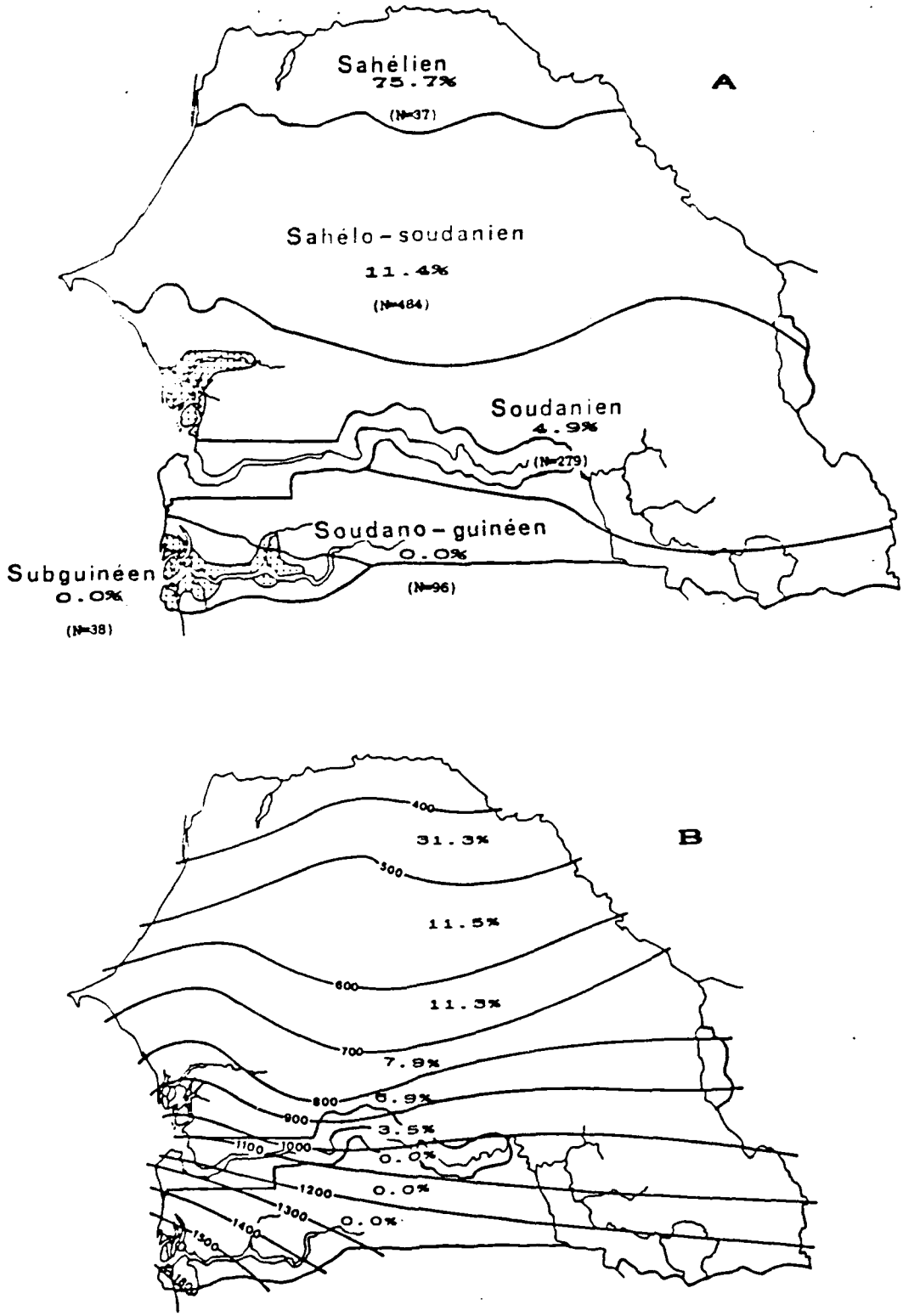


Figure 8. Average prevalence of anti-CCHFV IgG antibodies among sheep sampled throughout Senegal divided by (A) phytogeographic zones and (B) average annual rainfall (cm).

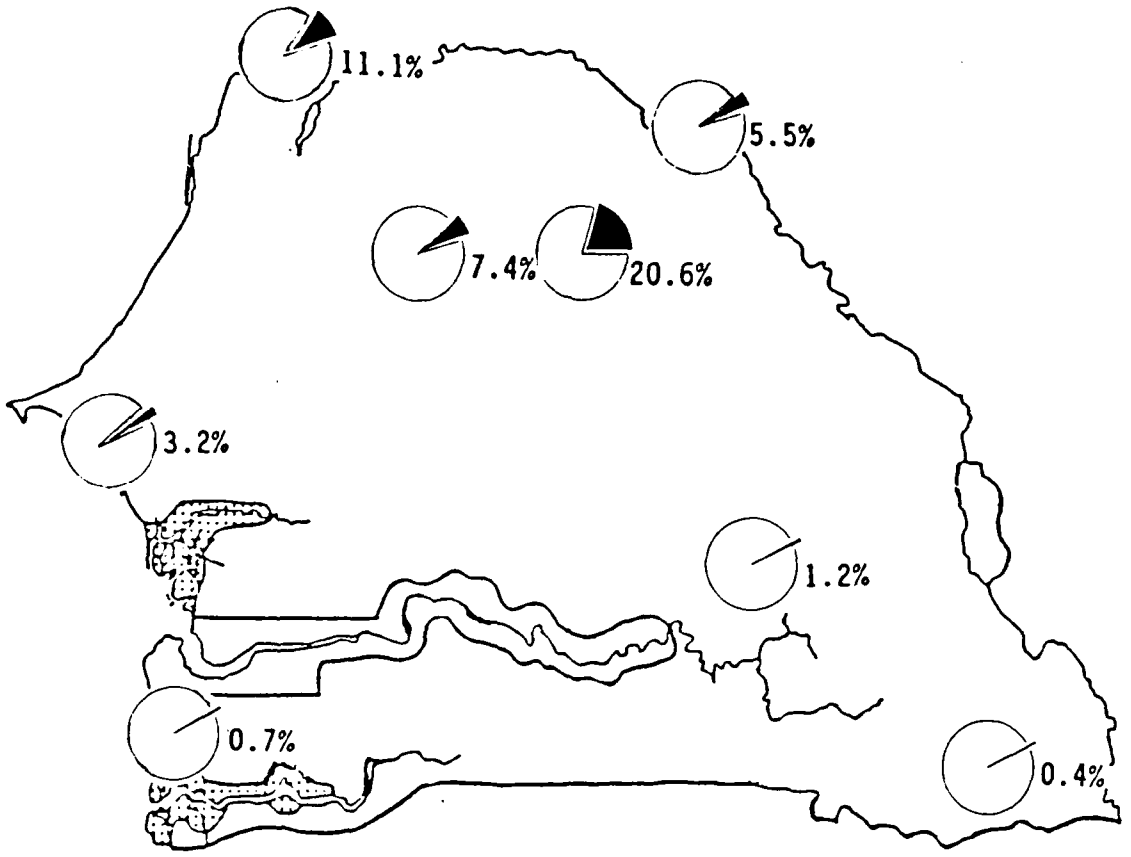


Figure 9. Prevalence of anti-CCHFV IgG antibodies among humans sampled in villages surrounding 8 major sites in Senegal.

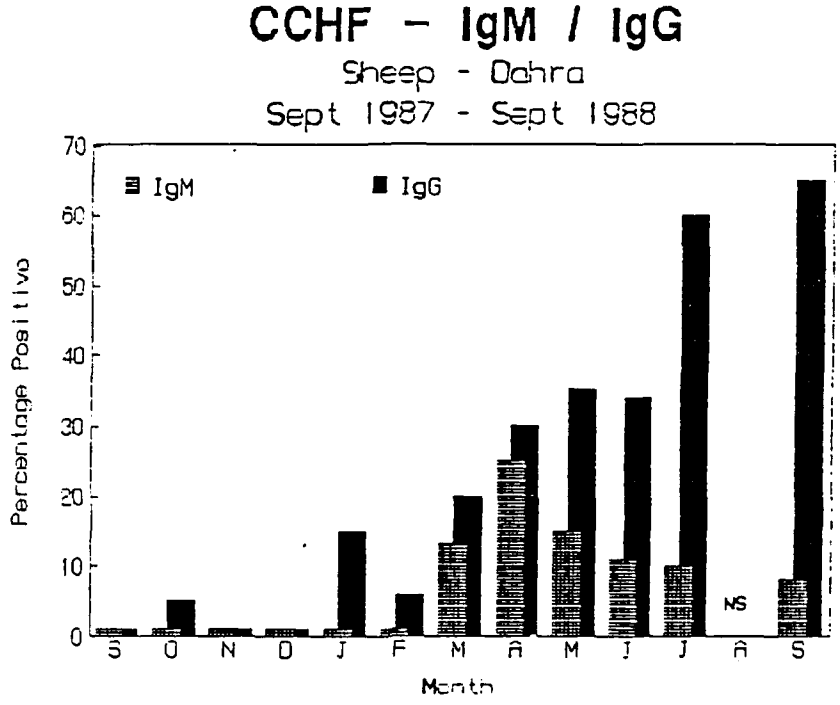


Figure 10. Prevalence of IgM and IgG antibodies among a herd of sheep at the Dahra Research Station, Senegal sampled monthly from September 1987 through September 1988.

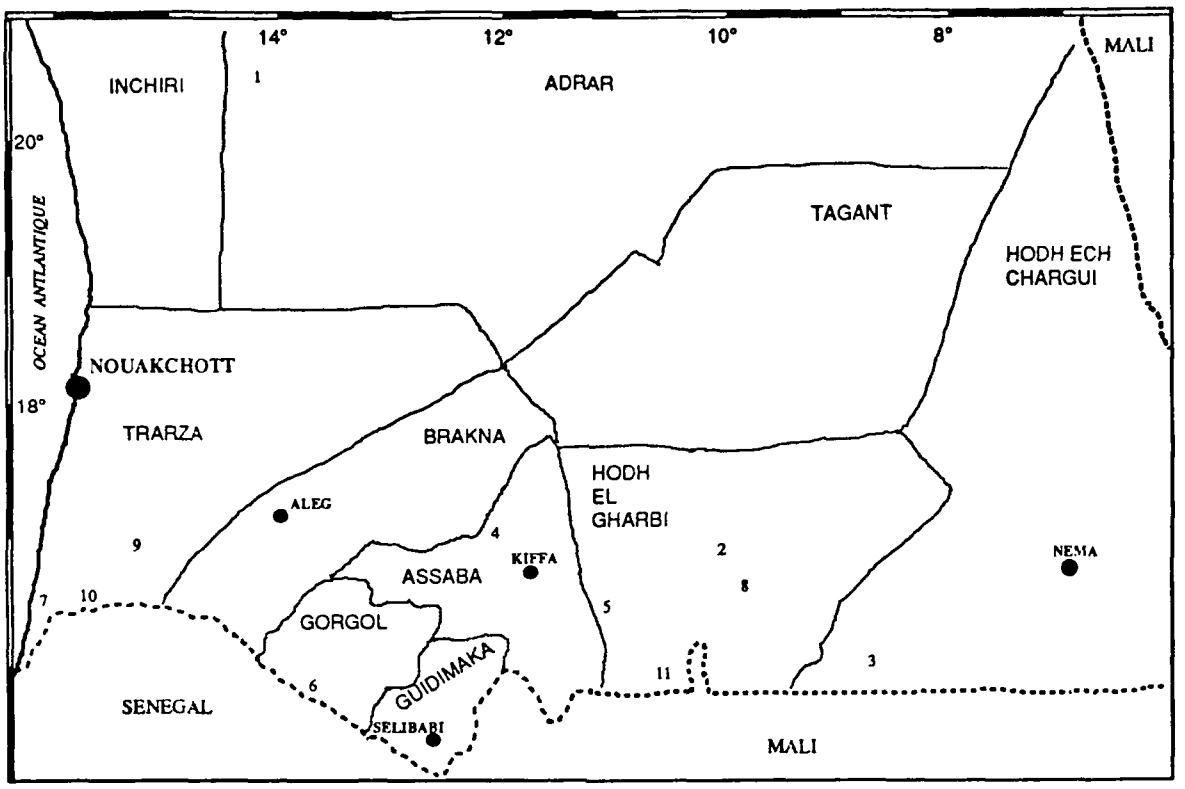


Figure 11. Map of southern Mauritania designating the districts and villages studied. Villages are: 1 Atar, 2 AycunElAtrous, 3 Bougdalia, 4 Guerou, 5 Infarba, 6 Kaedi, 7 Keur Massene, 8 Megdougou, 9 Rkiz, 10 Rosso, 11 Tuil.

Table 1. Additional personnel who have participated in the studies presented in this report.

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Table 2. Relative abundance of ticks feeding on domestic sheep, cattle and goats at selected sites in Senegal.

Tick Species[2]	Relative abundance[1] at Dahra	Yonofere	Nayies[3]	Bandia	Kolda[4]
H. truncatum	+++	+++	+++	+++	+
H. impeltatum	+++	+		+	
H. m. rufipes	+	+	++	++	+
H. impressum			+	+	
H. dromedarii	+	+			
A. varigatum		+	+++	++	+++
B. decoloratus			+++	+	
B. geigyi					+++
R. guilhoni	+++	+++	+	+++	+
R. e. evertsi	+	+	+	+	
R. sulcatus			+	+	+
R. lunulatus				+	
R. senegalensis			++		
R. muhsamae				+	

1. +++ = very abundant, ++ = modertely abundant, + = rare, ( ) = absent
2. Genera are: *Hyalomma*, *Amblyomma*, *Boophalus* and *Rhipicephalus*
3. Gueye *et al.*, 1986
4. Gueye *et al.*, in press

Table 3. Birds examined monthly at Yonofere, Senegal during February through December 1988, and immature ticks (*Hyalomma* spp.) found parasitizing them.

Bird (*Species*) or Tick	Month											
	F	M	A	M	J	J	A	S	O	N	D	F-D
Shikra *Accipiter badius*									1			1
Double-spurred Francolin *Francolinus bicalcaritus*								2	2	2		6
Stone-Partridge *Ptilopachyus petrosus*								1				1
Grey-Breasted Helmet Guinea Fowl *Numida meleagris*						2		2		2		6
Senegal Bustard *Eupodotis senegalensis*							3	4				7
Denham's bustard *Neotis denhami*							1					1
Laughing Dove *Streptopelia senegalensis*	3	4	4	15	18	4	2	1		1	3	55
Mourning Dove *Streptopelia decipiens*										1		1
Vinaceous Dove *Streptopelia vinacea*						2			1		6	9
Long-tailed Dove *Onea capensis*			1	2						1	4	8
Chestnut-bellied Sand-grouse *Pterocles exustus*						5	3		2			10
Abyssinian Roller *Coracias abyssinica*					6						1	7
Red-beaked Hornbill *Tockus erythrorhynchus*	1			3	1		1		2	3	2	13
Crag Chestnut-winged Starling *Onychognathuys morio*						8						8
Purple Glossy Starling *Lamprotornis splendidus*		1								1	1	3
Long-Tailed Glossy Starling *Lamprotornis caudatus*						4					1	5
Chestnut-bellied Starling *Spreo pulcher*										7		7
Yellow-fronted Canary *Serinus mozambicus*			9	19			14					42
Grey Canary *Serinus leucopygius*				1								1
Unidentified Weavers *Ploceus spp.*	5		18	13	59						1	96

CONTINUED.....

Table 3. Continued

Bird (*Species*) or Tick		Month F	M	A	M	J	J	A	S	O	N	D	F-D
Slender-billed Weaver *Ploceus luteolus*												11	11
Vitelline Masked Weaver *Ploceus velatus*							1					4	5
Village Weaver *Ploceus cucullatus*								1	9				10
Orange Weaver *Ploceus aurantius*					1								1
Scaly-fronted Weaver *Sporopipes frontalis*				5		1	11		2				19
Sparrow-Weaver *Plocepasser superciliosus*		7	6	3									16
Grey-headed Sparrow *Passer griseus*		2	5	5	8	34	10		2			17	83
Cut-throat Weaver *Amandina fasciata*									5			1	6
Warbling Silverbill *Lonchura malaburica*								1					1
Senegal Fire-Finch *Lagonosticta senegala*		13	10	7	5		6				7	4	52
ALL SPECIES		31	26	52	67	119	53	26	28	8	25	56	491
No. Birds Parasitised		0	0	0	2	1	0	0	2	0	2	5	12
Total Ticks	(Stage)												
H. rufipes	(Larva)	0	0	0	2	1	0	0	1	0	1	18	23
	(Nymph)	0	0	0	2	0	0	0	2	0	0	4	8
H. truncatum	(Larva)	0	0	0	0	0	0	0	0	0	0	0	0
	(Nymph)	0	0	0	0	0	0	0	0	0	1	0	1

Table 4. Monthly observations of immature Ixodid ticks found on small mammals examined during 1988 in Yonofere, Senegal.

Mammal Species[1]	Tick Sp.[2]	Tick Stage	Mean No. ticks on (N) mammals during: Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1988
Mastomys sp.	*H. trun.*	L	-	0	2	0	-	-	0	-	-	0	0	0
		N	-	0	0	0	-	-	0	-	-	0	0	0
			(0)	(10)	(3)	(3)	(0)	(0)	(3)	(0)	(0)	(1)	(18)	(38)
Taterillus sp.[3]	*H. trun.*	L	0	-	-	0	-	-	0	0	-	0	0	0.1
		N	0	-	-	0	-	-	0	0	-	2	0	0
			(4)	(0)	(0)	(1)	(0)	(0)	(1)	(1)	(0)	(1)	(1)	(19)
Lepus whytei	*H. trun.*	L	-	-	-	-	-	+?	-	-	0	0	0	0
		N	-	-	-	-	-	+?	-	-	3	3	2	8
	H. ruf.	L	-	-	-	-	-	+?	-	-	0	0	0	0
		N	-	-	-	-	-	+?	-	-	3	3	0	6
			(0)	(0)	(0)	(0)	(0)	(1)	(0)	(0)	(2)	(2)	(2)	(8)

1. In addition to those species listed, 3 non-parasitized *Arvicanthis niloticus* and were examined in November and 3 *Erinaceus albiventris* in April, July and August.
2. Tick species are *Hyalomma truncatum* and *H. marginatum rufipes*
3. The species within the genus *Taterillus* are visually indistinguishable; *T. pygargus* and *T. gracilis* are both encountered at this site.

Table 5. Monthly observations of immature Ixodid ticks found on small mammals examined during 1988 in Bandia, Senegal.

Mammal Species	Tick Sp.[1]	Stage	Mean No. ticks on (N) mammals during: Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Oct	Nov	Dec	1988
Mastomys erythroleucus	*H. trun.*	L	0	0	0.1	0	0	0	0	0	0	0	?	?
		N	0	<0.1	0	<0.1	0	0	0	0	0	0	?	?
	R. gui.	L	0	0	0	0	0	0	0	0	0	0	?	?
		N	<<0.1	0	0	0	0	0	0	0	0	0	?	?
			(38)	(26)	(26)	(15)	(20)	(10)	(10)	(14)	(15)	(32)	(56)	(262)
Arvicanthis niloticus	*H. trun.*	L	0	0	0.5	0.4	0	0	0	0	-	?	?	?
		N	1.3	0.4	0	0	0	0	0	0	-	?	?	?
	R. gui.	L	0.2	0.5	0	0	0	0	0	0	-	?	?	?
		N	2.8	1.1	0	0	0	0	0	0	-	?	?	?
			(6)	(16)	(4)	(5)	(4)	(10)	(1)	(3)	(0)	(10)	(5)	(64)
Taterillus sp.[2]	*H. trun.*	L	0	0	0	0	0.3	-	0	0	-	-	-	0.1
		N	0	0	0	0	0	-	0	0	-	-	-	0
			(7)	(1)	(3)	(2)	(4)	(0)	(1)	(1)	(0)	(0)	(0)	(19)
Myomys daltoni	*H. trun.*	L	0	0	-	0	-	-	0	-	0	0	0	0
		N	0	0	-	0	-	-	0	-	0	0	0	0
			(2)	(1)	(0)	(1)	(0)	(0)	(1)	(0)	(1)	(1)	(1)	(8)
TOTAL	*H. trun.*	L	0	0	0.1	0.1	0	0	0	0	0	?	?	?
		N	0.3	0.2	0	<0.1	0	0	0	0	0	?	?	?
	R. gui.	L	0	<<0.1	<<0.1	0	0	0	0	0	0	?	?	?
		N	0.2	0	0	0	0	0	0	0	0	?	?	?
			(51)	(44)	(37)	(23)	(28)	(20)	(13)	(18)	(16)	(43)	(62)	(353)

1. Tick species are *Hyalomma truncatum* and *Rhipicephalus guilhoni*.
2. The species within the genus *Taterillus* are visually indistinguishable; *T. pygargus* and *T. gracilis* are both encountered at this site.

Table 6. Prevalence of IgG antibodies against Crimean-Congo Hemorrhagic Fever Virus among 942 sheep sampled from 70 villages in 22 zones of 7 Regions of Senegal during November, 1986 - January, 1987.

Region	Zone No.	No. Villages	No. Sheep Tested	Ratio M:F	IgG Positive No.	IgG Positive %age
Fleuve	41	2	37	1:8.3	28	75.7%
	44	1	9	1:2.0	2	22.2
	47	1	16	1:1.7	5	31.3
	50	3	30	1:3.3	1	3.3
Louga	23	9	78	1:10.1	8	10.3
	26	7	192	1:11.8	25	12.9
	29	4	60	1:3.3	8	13.3
	32	4	60	1:2.2	1	1.7
Thies	77	4	48	1:2.4	0	0
Diourbel	2	3	44	1:3.0	4	9.1
Sine Saloum	5	3	41	1:7.2	9	22.0
	8	3	65	1:4.9	3	4.6
	11	3	33	1:7.3	4	12.1
Senegal Oriental	53	2	20	1:4.0	0	0
	56	2	21	1:20.0	0	0
	59	2	22	1:4.5	0	0
	62	1	12	1:3.0	0	0
	65	2	21	1:20.0	0	0
Casamance	14	4	43	1:6.5	0	0
	17	1	19	1:18.0	0	0
	20	4	34	1:5.8	0	0
	80	5	37	1:2.1	0	0
TOTAL	--	70	942	1:4.7	98	10.4

Table 7. Association between the prevalence of IgG antibodies against Crimean-Congo Hemorrhagic Fever Virus among 937 sheep and 5 biogeographic zones of Senegal in which they were sampled.

Bio-Geographic Zone[1]	Avg. Annual Rainfall (mm.)	Dominant Tree Species	No. Sheep Tested	Percent IgG Positive
Sahelian	200-450	*Acacia radiana* *A. nilotica* *Tamarix senegalensis*	37	75.7%
Sahelo -sudanian	450-700	*A. nilotica* *A. albida* *Combretum glutinsoum*	484	11.4
Sudanian	700-1200	*Parkia biglobosa* *C. glutinsoum* *Oxytenathera abyssinica*	279	4.9
Sudano -guinean	1200-1400	*P. biglobosa* *Parinari excelsa* *Borassus flabellifer*	96	0
Sub-guinean	1400-1800	*Elaeis guineensis* *P. biglobosa*	38	0

1. Zones based on the classification of Ndiaye (1983)

Table 8. CCHF antibody titers of patients hospitalized in Rosso, Mauritania during May 1988 for suspicion of Hemorrhagic Fever.

Case Number	Village	Antibody Titre[1] IgM	IgG
1	Satara III[2]	400	80 000
2	Ndeyboussat	-[3]	12 800
3	Ndeyboussat	-	12 800
4	Thioury[2]	-	3 200
5	Thioury[2]	-	1 600
6	PK28	-	6 400
7	Satara III	-	-
8	PK47	-	-

1. ELISA test
2. Patient died
3. Negative

Table 9. Prevalence of anti-CCHF antibodies among contacts of patients hospitalized with Hemorrhagic Fever from the Trarza district of Mauritania.

Village	Case[1] Contact	No. Tested	No.(%) positive: IgM	IgG
Mbalal	1	7	0 (0%)	1 (14%)
Ndeyboussat	2,3	82	1 (1)	32 (39)
Thioury	4,5	10	0 (0)	3 (30)
Total	-	99	1 (1)	36 (36)

1. Case contact number refers to the hospitalized cases from Table 8.

Table 10. CCHF virus-antibody prevalence among patients hospitalized during May - July, 1988 in Rosso, Mauritania for symptoms suggesting viral Hemorrhagic Fever.

Month	No. Tested	No.(%) positive IgM	No.(%) positive IgG
May	9	1 (11%)	7 (78%)
June	13	0 (0)	5 (39)
July	14	0 (0)	2 (14)
Total	38	1 (3)	14 (37)

Table 11. CCHF-IgG antibody prevalence and tick infestation rates among domestic ungulates from nomadic herdsmen's camps in southern Mauritania.

	Prevalence of antibody and tick parasitism[1] in							
	Sheep		Goats		Donkeys		Camels	
Village	IgG	Ticks	IgG	Ticks	IgG	Ticks	IgG	Ticks
Ndeyb	0/5	24/60	2/7	28/61	0/1	12/12	NT	1/2
Thioury	3/6	6/6	NT[2]	NT	0/2	2/2	2/2	NT
Total	3/11	30/67	2/7	28/61	0/3	14/14	2/2	1/2

1. Presence of *Hyalomma impeltatum* and/or *H. dromedarii*.
2. Not Tested

Table 12. CCHF antibody prevalence among sheep from southwestern Mauritania in 1988.

Phyto-geographic Zone	District[1]	No. Tested	No. (%) Positive IgG	No. (%) Positive IgM
Sub-sahelian	Trarza	127	52 (40.2%)	8 (6.3%)
	Hodh	482	99 (20.5)	10 (2.1)
	Gorgol	152	16 (10.5)	4 (2.6)
	Assab	33	8 (24.2)	0 (0)
Sahelian	Adrar	65	4 (6.1)	0 (0)

1. Districts are indicated in Figure 11.

Table 13. Ticks taken from ungulates, small mammals and rodent burrows in Yonofere, Dahra, and Bandia, Senegal during 1988 that were tested for the presence of arboviruses.

Tick Species[1]	No. of ticks tested: TOTAL	Female	Male	Nymph	Larvae	No. Pools
YONOFERE						
H. truncatum	6740	2445	4285	0	0	345
H. impeltatum	128	42	86	0	0	14
H. rufipes	72	21	51	0	0	14
R. guilhoni	2811	1095	1716	0	0	149
Ap. flavomaculatum	19	4	15	0	0	1
DAHRA						
H. truncatum	1872	558	1314	0	0	103
H. impeltatum	2347	618	1729	0	0	128
H. rufipes	6	1	5	0	0	4
H. dromedarii	1	0	1	0	0	1
R. guilhoni	104	40	64	0	0	9
R. evertsi	20	5	15	0	0	5
BANDIA						
H. truncatum	314	131	183	0	0	38
H. rufipes	130	47	83	0	0	26
H. impressum	10	2	8	0	0	6
R. guilhoni	569	254	315	0	0	44
R. evertsi	5	2	3	0	0	4
R. sanguineus	8	0	8	0	0	3
Am. variegatum	79	1	5	33	40	13
B. decoloratus	2	1	0	1	0	2
O. sonrai	202	31	99	72	0	4
TOTAL	*15439*	*5308*	*9985*	*106*	*40*	*913*

1. Genera are *Hyalomma*, *Rhipicephalus*, *Aponema*, *Amblyomma*, *Boophilus*, and *Ornithodorus*.

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